Appendix 2

Making XY Graphs in Microsoft Excel

Graphs are characteristic of scientific and technical writing. They help the reader to visualize the data, and to see relationships among variables. Graphs are a way to summarize information that would otherwise involve lengthy descriptions that would be difficult to interpret.

Years ago, authors used drawing instruments, specially lined graph paper, and ink to make figures for published papers. Mistakes were difficult, if not impossible to correct, so any mistake usually resulted in starting over. If a different sized figure was required, the entire figure had to be redrawn. The advent of plotting software in the mid-1980s, however, has made hand-drawn graphs practically obsolete. You simply enter the data into a graphics program in a prescribed manner and select the desired form for the graph; the computer draws the graph for you.

The most common types of graphs are **line graphs**, **bar graphs**, and **pie charts**. The type of graph you choose should be based on which one best depicts and emphasizes the trends shown by your data. Some guidelines for helping you choose an appropriate type of graph are given in Chapter 4.

This appendix gives you step-by-step instructions for making XY graphs in Microsoft Excel. Excel is a good plotting program for novices for the following reasons:

- Data input and subsequent plotting of these data is relatively straightforward in Excel.
- Excel is readily available and is included in the Microsoft Office suite of computer software.
- If your school has Excel on its computers, it's likely that you can get assistance from a staff member in your school's computer services department.

The time you invest now in learning to plot data on the computer will be invaluable in your upper-level courses and later in your career. You may eventually switch to a higher-powered plotting program such as SigmaPlot, but the experience gained by working with Excel should make this transition easier.

The format described in this appendix follows the Council of Science Editors' recommendations (CBE Manual, 1994). Instructions to "single-click" or "double-click" refer to clicking the *left* mouse button, unless otherwise noted.

The screen drops in this appendix are for Word 2003, but the instructions apply to earlier versions as well, unless otherwise noted. Excel commands are distinguished in this appendix with a vertical bar, separating commands from subcommands. For example, **Tools | Customize | Options** means "Click the Tools button (on the menu bar), then select Customize, and then select the Options command."

The Microsoft Excel Screen

Click the **Excel** button on the taskbar at the bottom of your screen to open an Excel worksheet (spreadsheet). Alternatively, find Microsoft Excel under **Start | All Programs | Microsoft Office | Microsoft Office Excel**. A worksheet consists of thousands of cells arranged in rows and columns, with menus and toolbars located above the cells at the top of the screen display (Figure A2.1). The columns have letter headings (A, B, C, etc.) and the rows have numerical headings (1, 2, 3, etc.).

Title bar

The title of the worksheet is given at the very top of the page on a blue background. If you have not yet named the worksheet, the title bar will read **Microsoft Excel–Book 1**.

Figure A2.1 Screen display of Excel 2003 worksheet

Excel 2003 Update

The Microsoft Office XP programs Excel 2002 and Excel 2003 look different from their predecessors. The new default window is split into the **Document** pane and the **Task** pane (Figure A2.2).

The Task pane appears when you choose certain commands or when you click **View | Task pane** on the menu bar. To switch to another Task pane, click the title bar at the top of the Task pane. To close the Task pane, click the **Close** box (☒) in the top right corner of the Task pane.

Menu bar

Just below the title bar is the menu bar. The menu bar consists of buttons that, when clicked, list other commands in pulldown menus. For example, when you click **File**, the pulldown menu shown in Figure A2.2 is displayed.

Toolbars

If your Excel program has been set up to display toolbars (Standard and Formatting), they are displayed just below the menu bar. Toolbars contain pictorial buttons that are shortcuts to menu commands.

If the Standard and Formatting toolbars are not displayed, go to the menu bar and select **View | Toolbars** to see if there is a checkmark next to **Standard** and **Formatting**. If there is no checkmark, go to the last item on the Toolbars pulldown menu and click **Customize**. Click the boxes next to **Standard** and **Formatting**, then click **Close**.

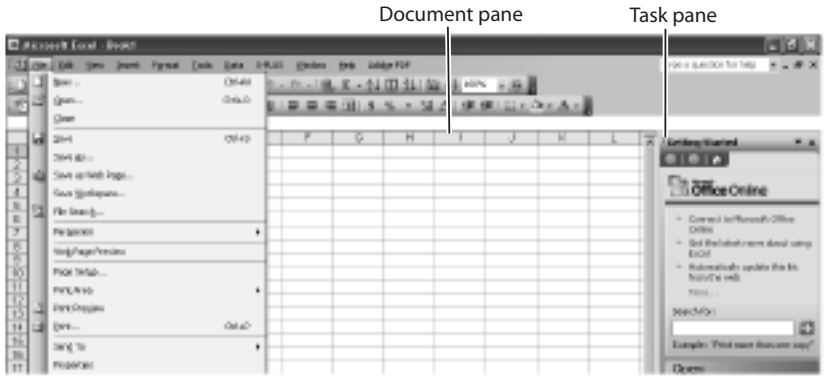

Figure A2.2 Pulldown menu for File command

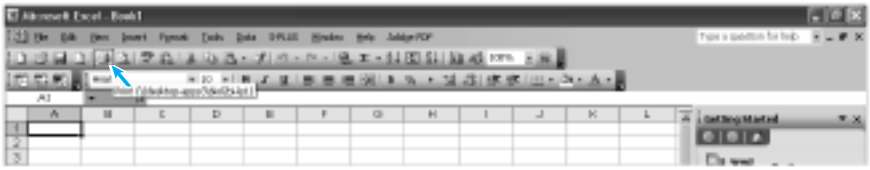

Figure A2.3 Selecting the Print button on the Standard toolbar

When you place the mouse pointer over a particular button on the toolbar or menu bar (do not click any mouse buttons), a description of that button will appear. For example, if you place the mouse pointer on the 5th button from the left on the Standard toolbar (Figure A2.3), the **Print** command, with the default printer in parentheses, will appear in a pop-up label. The **Print** command is also found on the menu bar under **File | Print**.

Note: Shortcuts offer only one option from the corresponding menu command. For example, if you click the **Print** button on the Standard toolbar, the entire document will be printed on the default printer. If you want to print single pages or use a different printer, you must go to the menu bar and select the desired options from the **File | Print** pull-down menu.

Formula bar

The formula bar is located just below the toolbars. It is used to enter formulas for performing calculations on the data entered in the spreadsheet. It is also used to edit the contents of a cell.

Entering Data in Spreadsheet

Before you enter data in an Excel worksheet, you must first have a clear idea of what your XY graph should look like. Which parameter should be plotted on the *x*-axis and which one on the *y*-axis? By convention, the *x*-axis of the graph shows the independent variable. The independent variable is the one that the scientist manipulated during the experiment. The *y*-axis of the graph shows the dependent variable, the variable that changes in response to changes in the independent variable.

Let's say you conducted an experiment in which you determined how the activity of an enzyme (catalase) changed when you varied the temperature. Because you manipulated the temperature in the experiment,

	A	B	C	D	E
1					
2					
3					
4					
5					

TABLE A2.1
Portion of Excel spreadsheet

temperature is the independent variable and should be plotted on the *x*-axis. Catalase activity is the dependent variable because it changes in response to changes in the temperature, and should be plotted on the *y*-axis.

On the Excel spreadsheet, **Column A** is used to enter the data for the ***x*-axis**, whereas subsequent columns are used for data for the ***y*-axis** (Table A2.1). In the previous example, temperature data would be plotted in Column A and the corresponding catalase activity data would be plotted in Column B.

Enter the data as in Table A2.2. For a simple graph with only one data set, it is not necessary to provide column headings.

TABLE A2.2 Sample data for effect of temperature on catalase activity. Temperatures (°C) are entered in Column A, catalase activity (units of product formed • sec^{-1}) in Column B.

	A	B
1	4	0.039
2	15	0.073
3	23	0.077
4	30	0.096
5	37	0.082
6	50	0.04
7	60	0.007
8	70	0
9	100	0

TABLE A2.3 Excel-specific terminology

EXCEL TERM	DESCRIPTION
Chart	Graph
Category axis	*x*-axis
Value axis	*y*-axis
Data series	Set of related data points
Plot area	Area of the graph inside the axes
Chart area	Area outside the axes but inside the frame
Legend	Legend or key

Terminology

The terminology that Excel uses for graphs is different from what biologists use. For example, you have already learned that Excel calls a spreadsheet a worksheet. The Excel instructions provided here use the terms biologists use, rather than those chosen by Excel. It is helpful to know the Excel terminology when you use the Help menus, however, and Table A2.3 translates some common Excel terms into biologists' terms.

Using Chart Wizard to Plot the Data

1. In the spreadsheet, **select the data to be plotted using the mouse**. To do this, single-click the left mouse button on the first cell, and keep holding the button down as you drag the mouse pointer over the rest of the cells that contain the data to be plotted. When you release the mouse button, the cells you selected are highlighted in blue. Alternatively, click the top left box of the block of data, hold down the **Shift** key, and click the bottom right box of the block. All the selected cells are highlighted in blue.

   Note: If the data to be plotted are not in adjacent columns, highlight the first column, hold down the **Ctrl** key, and then highlight the data in any other column(s).

2. **Click Chart Wizard on the Standard toolbar**. The **Chart Wizard** button is a colored bar graph (Figure A2.4). Using four sequential dialog windows, Chart Wizard walks you through the steps needed to make a first draft of your graph.

3. Chart Wizard Step 1 of 4—Chart Type allows you to **select the type of plot** (Figure A2.5).

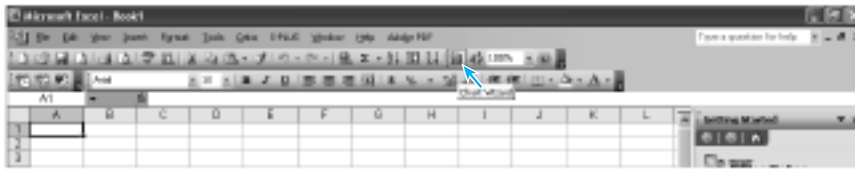

Figure A2.4 Selecting Chart Wizard on the Standard toolbar

- To make a line graph, select **XY (Scatter)**. Do *not* select **Line**, because this option spaces the *x*-axis values at equal intervals, instead of according to the intervals of the data.
- For Chart sub-type, you must decide whether the points should be connected or not (see Chapter 4 for an explanation of these formats). If there are only a few data points, and you want to show the relationship between the independent variable and the dependent variable, then select **Data points connected by smoothed or straight lines**. Usually your instructor wants to see the data points, so do *not* select the options in which Excel plots the curve without

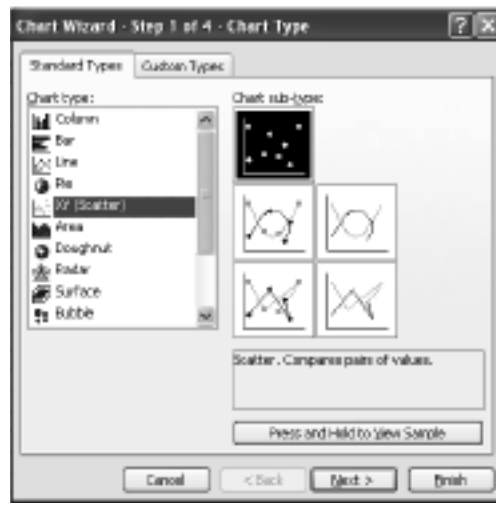

Figure A2.5 Selecting a type of graph in Chart Wizard, Step 1 of 4. Current selection is XY Scatter with unconnected data points.

displaying the data points. If you are making a standard curve or a scatter plot, then select **Scatter with no points connected**.

- Click **Next**.

4. Chart Wizard Step 2 of 4—Chart Source Data tells you which cells you selected on the spreadsheet. **The data series should be in Columns**. Click **Next**.
5. Chart Wizard Step 3 of 4—Chart Options shows you five tabs: **Titles**, **Axes**, **Gridlines**, **Legend**, and **Data Labels** (Figure A2.6).

Titles

Chart Title: Leave blank if this graph is for a lab report or poster. By doing so, Excel will make a larger graph for you to import into your text document later. In the text document, type the figure caption *under* the figure. **Add a title** if the graph is for an oral presentation.

Value (*X*) axis: Enter the *x*-axis label with the units in parentheses. For the data in Table A2.2, the *x*-axis label would be: Temperature (°C). For the time being, don't type the degree sign. You can copy and paste it later (see the section on "Format Axis Label").

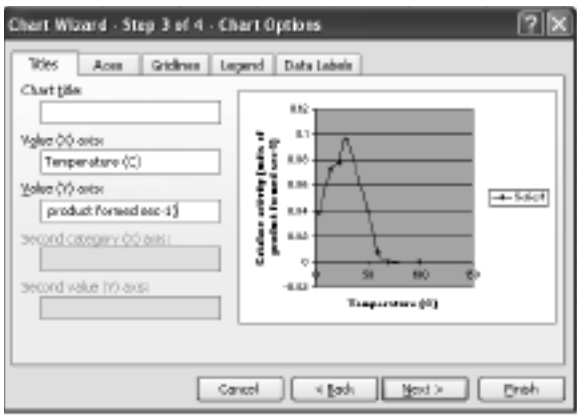

Figure A2.6 Dialog box in Chart Wizard, Step 3 of 4 for entering title and axis labels and hiding or displaying gridlines and legends

Value (*Y*) axis: Enter the *y*-axis label with the units in parentheses. For the data in Table A2.2, the *y*-axis label would be: Catalase activity (units of product formed • sec^{-1}). For the time being, leave out the raised dot and simply type "–1" for the exponent.

Axes

No changes.

Gridlines

There should be no gridlines on the figure. Clear the box next to Value (*Y*) axis: Major gridlines.

Legend

No legend (key) is required when there is only one line on the graph. Clear the box next to Show legend.

Data labels

None.

When you have finished with these five tabs, click **Next**.

6. Chart Wizard Step 4 of 4—Chart Location asks you if you want the figure to be printed as a new sheet or as an object in the current sheet.
   - By convention, figures are placed as close as possible to the location in the scientific paper where they are first described. Because you have to import the graph into a text document anyway, it does not really matter whether you choose **As object in Sheet 1** or **As new sheet**. Selecting **As object in Sheet 1** has the advantage that graph size is uniform when the object is imported into the text document. You can, however, adjust the size of the graph in the text document with either option.
   - If the figure will be mounted on a poster or attached as a separate sheet at the end of the lab report, then select **As new sheet**.
   - Click **Finish**. Your graph should look like Figure A2.7.
7. Inspect the graph carefully. Look for proper units and spacing on the *x*- and *y*-axes, for appropriate labeling of the axes, and for expected trends of the line itself. If you notice that you entered a datum incorrectly in the spreadsheet, simply change it, and the correction will also be made in the graph.

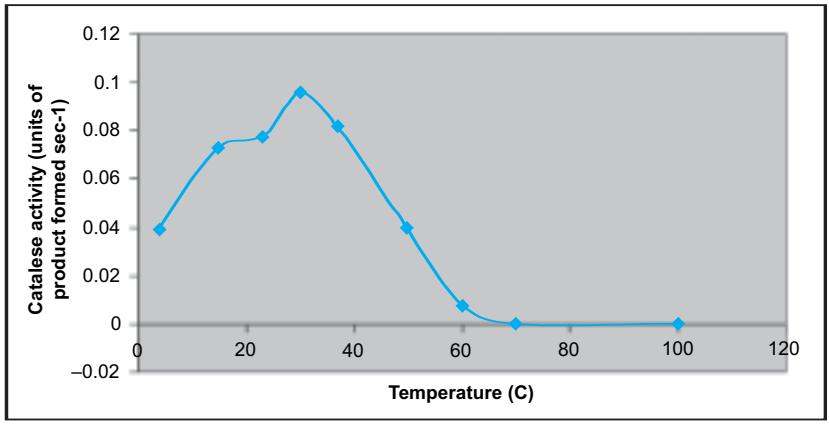

Figure A2.7 First draft of Table A2.2 data plotted by Chart Wizard. See Figure A2.13 for the final form.

Modifying Graphs

Graphs produced by Chart Wizard can be modified to meet an instructor's or a journal's specifications. The modifications described in this section follow the guidelines given in the CBE Manual (1994). To modify a graph, first activate it by single-clicking the plot area or chart area (Figure A2.8). Then click the **Chart** button on the menu bar. You can return to any of the four steps of Chart Wizard (Chart Type, Source Data, Chart Options, and Location), or you can select **Add Data** (type in range of new data to be plotted from spreadsheet) or **Add Trendline**.

In Excel 2000 and later versions, when you single-click the plot area or chart area, a floating toolbar with **Chart** commands appears on the screen (Figure A2.9). If it doesn't, click **View | Toolbars** and check the box next to **Chart**. Select any of the **Chart** options in the pulldown menu, then click the **Format** button to change the format of that particular option. There are more options under the **Chart** command on the menu bar than on the floating toolbar.

Note: The **Chart** command will not be displayed on the menu bar unless you first activate the graph (click inside the chart or plot area to activate the graph).

Chart Type

If you want to see what the data look like plotted in another form, select **Chart | Chart Type**. Select a different type of graph, and click the **Press**

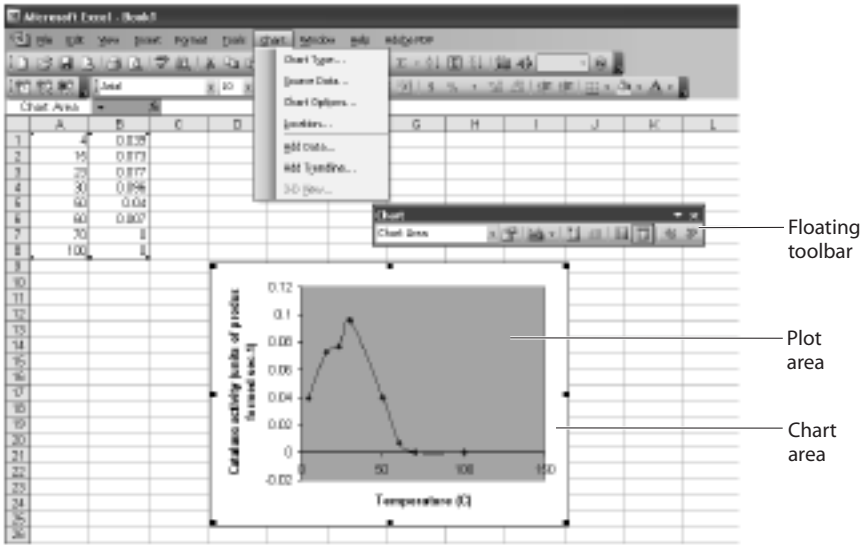

Figure A2.8 Formatting options available when chart is activated: Floating toolbar or Chart button on the menu bar

and Hold to View Sample button. Check with your instructor regarding what chart type is appropriate.

Source Data

If you want to change the range of the cells used to plot the graph, you can do so in this dialog window. This might be appropriate if you added or deleted data values in the spreadsheet.

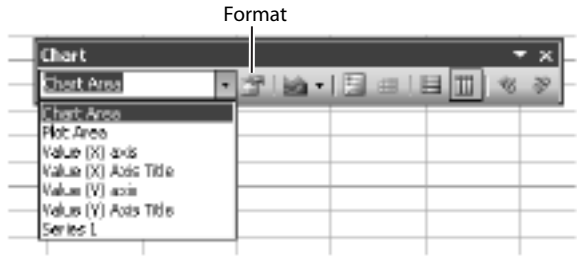

Figure A2.9 Floating toolbar options for formatting different parts of the graph

Chart Options

This allows you to change the *x*- and *y*-axis labels and delete gridlines and the legend. The **Axes** tab seems to suggest that the format of the axes can be changed here, but this is misleading. For more information, see the section on "Format Axes."

Location

If you expect to insert the figure into a Word document (this is preferred when writing a lab report), place the figure as an object in the worksheet. If you plan to mount the graph on a poster or attach it as a separate sheet at the end of the document, select **As new sheet**.

Add Data

To add data to an existing figure, first enter the new data in cells on the spreadsheet. Then click the chart area of the existing figure, select **Chart | Add Data**, and change the range of cells.

Add Trendline

A trendline is a line that describes the general tendency of the data points. In Excel you can add any of six trendlines or regression lines (best-fit lines) to a data set. Excel automatically calculates the *R*-squared value and the equation of the line. The equation allows you to predict one variable when the other is known. The *R*-squared value gives you an indication of how well the line fits the data points (the closer to 1, the better the fit). See the section on "Trendlines" for situations when trendlines may be added to a data set.

Format Data Series

Excel's hierarchy for symbols used in multiple line graphs is not the same as that recommended by the Council of Science Editors (CBE Manual, 1994). The two hierarchies are compared in Table A2.4.

The symbols that science editors use are based on ease of recognition and good contrast in black and white journal publications. The criteria used by Excel to determine symbol hierarchy are not obvious, especially since light colored symbols are very hard to see on a white background.

To change the symbol style and/or color in Excel, double-click the line or the symbol to open the **Format Data Series** window (Figure A2.10). On the **Patterns** tab:

TABLE A2.4 Comparison of Excel and CBE Manual symbol hierarchy for line graphs

EXCEL	CBE MANUAL
Navy blue diamond	Black open circle
Pink square	Black filled circle
Yellow triangle	Black open triangle
Turquoise x	Black filled triangle
Purple x with additional vertical line	Black open square
Brown diamond	Black filled square

- Change **Line Color** from Automatic to Black.
- Change the **Marker** (symbol) to a circle, triangle, or square by selecting the desired symbol next to **Style**. Next to **Foreground**, choose **Black**. Next to **Background**, choose **No color** to make an open circle, triangle, or square; or **Black** to make a filled circle, triangle, or square.

Figure A2.10 Patterns tab inside Format Data Series dialog box, opened by double-clicking a data series (line or symbol) on a line graph

Format Plot Area

Traditionally, scientific journals are published in black and white. With this in mind, make the background color (plot area) **white** for best contrast. To select the background color, double-click the plot area (area inside the axes). In the **Format Plot Area** dialog box, set the **Area** to None. Set the **Border** to None. Click **OK**.

Format Chart Area

Graphs in scientific journals do not have a border. To remove the border that Excel automatically creates around the figure, double-click the chart area (area outside the axes, but inside the frame). In the **Format Chart Area** dialog box, set the **Border** to None. The default for the **Area** (white) is fine.

Format Legend

The background color of the legend (key) is usually white and there is no border. Double-click the legend to open the **Format Legend** dialog box. On the **Patterns** tab, set the **Border** to None and leave the default selection for **Area**: Automatic (white). Click **OK**.

When possible, place the legend within the plot area. This is done by single-clicking the legend (selection handles will appear) and dragging it to the desired location.

Format Axes

Use the criteria in Table A2.5 to check that the axes have been formatted correctly. If any changes need to be made, double-click any number on either the *x*- or *y*-axis (depending on which axis needs to be changed). This action opens the **Format Axis** dialog box (Figure A2.11). Five tabs are displayed: **Patterns**, **Scale**, **Font**, **Number**, and **Alignment**. Click the appropriate tab (see Table A2.5) and make the necessary changes.

Format Axis Label

Use the criteria in Table A2.6 to check that the *x*- and *y*-axis labels have been formatted correctly. If any changes need to be made, double-click the appropriate label. This action opens the **Format Axis Title** dialog box (Figure A2.12). Three tabs are displayed: **Patterns**, **Font**, and **Alignment**. Click the appropriate tab (see Table A2.6) and make the necessary changes.

To **superscript** or **subscript** certain characters in the *x*- and *y*-axis labels, or in the legend, single-click the text box to activate the label. Use

Figure A2.11 Scale tab inside Format Axis dialog box, opened by double-clicking any number on either the *y*-axis or the *x*-axis

the mouse to select the character(s) to be super- or subscripted, and then select **Format | Selected Axis Title** on the menu bar. On the **Font** tab, select either super- or subscript in the **Effects** category. Click **OK**.

Inserting Greek Characters and Other Symbols in Axis Labels

Greek characters and **other symbols** can be inserted into axis labels by using two straightforward methods: copying and pasting the symbol or character from a Word document, or by selecting the symbol from the Character Map.

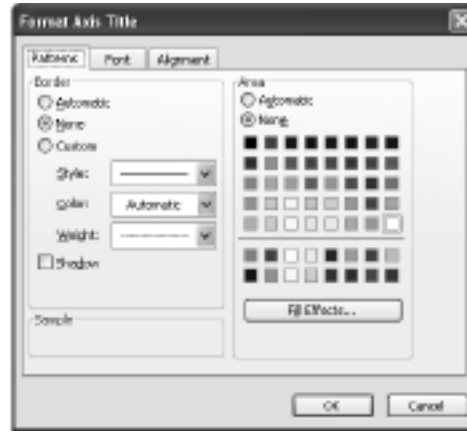

Figure A2.12 Patterns tab inside Format Axis Title dialog box, opened by double-clicking either the *y*-axis or the *x*-axis label

TABLE A2.5 Checklist for axis format

CORRECT FORMAT	HOW TO ADJUST
Dependent variable on *y*-axis	See "Entering Data in Spreadsheet"
Independent variable on *x*-axis	See "Entering Data in Spreadsheet"
Range of values on axes is slightly larger than range of data values being plotted	Scale tab | Min, Max If negative values are not appropriate for the quantity plotted, Min = 0.
Axis numbers are multiples of 2, 5, or 10 whenever possible	Scale tab | Major unit Minor units are not displayed, so leave the default selection.
If scale includes axis numbers less than 1, a zero is required before each decimal point	See "Entering Data in Spreadsheet"
Tick marks are left of the *y*-axis and below the *x*-axis	Patterns tab | Major tick mark type: Outside
Tick marks should always be accompanied by a number (no subdivisions between numbered marks)	Patterns tab | Minor tick mark type: None
Numbers should be centered on their respective tick marks, outside the field of the graph	Patterns tab | Tick mark labels: Next to axis
Numbers should be the same size and should read horizontally	Alignment tab | Orientation | Automatic

Copy and Paste from Word document

1. Type the desired symbol in Microsoft Word (see Appendix 1, Section 4.1 or 4.5).
2. Select the symbol and click **Edit** | **Copy** on the menu bar.
3. In your Excel file, single-click the axis label that contains the special symbol. Put the cursor where you want to insert the symbol. Click **Edit** | **Paste**.

Select Symbol from Character Map

1. For PCs, click the **Start** button located in the lower left corner of your screen. Select **All Programs** | **Accessories** | **System Tools** | **Character Map**.
2. In the Font section located at the top of the **Character Map** window, scroll down to **Symbol** and highlight it.

TABLE A2.6 Checklist for axis label format

CORRECT FORMAT	HOW TO ADJUST
Capitalize only the first word of the label and any proper nouns	Retype
A word or a phrase that accurately describes the variable	Retype
Centered on the length of the axis	Alignment tab | Text alignment Horizontal: Center Vertical: Center Orientation: 0 degrees
Vertical axis labels read parallel to the *y*-axis (they should never read vertically downward)	Alignment tab | Text alignment Vertical: Center Orientation: 0 degrees
Units of measurement for the variable are placed in parentheses after the variable	Retype
Font typeface and size	Font tab Font: Arial or another *sans serif* font Font style: Regular or bold Size: At least 10pt
Superscripted or subscripted characters	See below
Special characters (e.g., Greek letters)	See below
No borders or background	Patterns tab Border: None Area: Automatic (white)

3. Locate the symbol you want to include on the axis label, and single-click it. Let's use μ (Greek mu) as an example.
4. Click the **Select** button and then the **Copy** button at the bottom of the **Character Map** window.
5. In your Excel file, single-click the axis label that contains the special symbol. Put the cursor where you want to insert the symbol. Click **Edit | Paste**.
6. Use the mouse to highlight the "m" that you want to change to μ.
7. On the formatting toolbar, click the arrow button next to the **Font** box and select **Symbol**.

Applying CBE Guidelines to Figure A2.7

The criteria listed in the previous section can now be used to evaluate the graph produced by Chart Wizard (see Figure A2.7). Problems with the graph and how to correct them are summarized in Table A2.7. The final form of the graph is shown in Figure A2.13.

Make sure you make all of the necessary modifications and corrections before you copy the graph into your text document (see the next section on "Importing Graphs into Microsoft Word") or before you print it out.

Importing Graphs into Microsoft Word

In order to give your lab report a professional appearance, insert figures as close as possible to the location in the document where they are first mentioned. This can be done easily by copying the graph you made in Excel and pasting it into a Microsoft Word document (this method also works for WordPerfect documents).

Here are some tips that will help you carry out this task:

1. **Make all modifications and corrections to the graph in Excel**. Once it is imported into the Word document, it is no longer possible to make any changes (except to the size of the graph).

Catalase activity peaked at 30°C (Figure 1). From 4 to 30°C, activity steadily increased to a maximum of 0.096 units of product formed • sec^{-1}, and then activity fell with increasing temperature until there was no activity beyond 70°C.

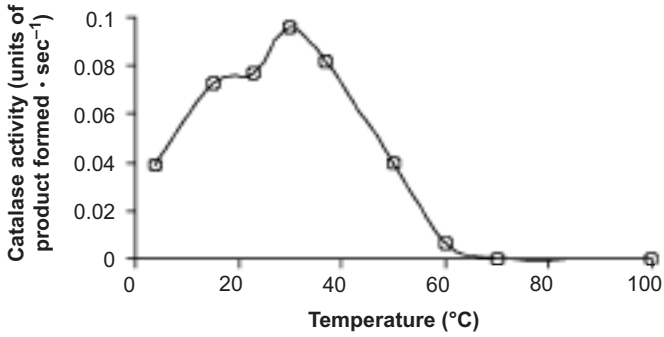

Figure 1 Effect of temperature on catalase act

Figure A2.13 Excerpt from a Results section in which the description of the results precedes the figure, the figure is referenced parenthetically, and the figure is formatted properly

TABLE A2.7 Problems with Figure A2.7 and how to remedy them

PROBLEM	REMEDY
Plot area (background) should be white, not gray; plot area should not have a border	Double-click plot area to open Format Plot Area dialog box. Select: Border: None Area: None or white
Chart area should not have a border	Double-click chart area to open Format Chart Area dialog box. Select: Border: None Area: Default (white) or none
Symbol is a blue diamond; it should be a black open circle	Double-click data series (line or symbol) to open Format Data Series dialog box. Select: Line Color: Black Marker Style: Circle Foreground: Black Background: None (for an open symbol)
Range of values on axes 1. *x*-axis: 0 to 120 is 20% larger than needed 2. *y*-axis: Negative rates don't make sense. Minimum value should be zero. Maximum value should be 0.1.	Double-click any number on the respective axis. 1. On the Scale tab for the *x*-axis, change Max to 100. 2. On the Scale tab for the *y*-axis, change Min to 0 and Max to 0.1.
Axis labels 1. Font size: at least 10 pt 2. *x*-axis: Insert a degree symbol (°) 3. *y*-axis: Superscript –1 4. *y*-axis: Insert raised dot (·)	Single-click the respective axis label. 1. Format | Selected Axis Title on the menu bar. On the Font tab, Size: 10 pt or larger 2. Insert a degree symbol in Word (Insert | Symbol | °), then Copy and Paste it into the *x*-axis label; alternatively, in Excel, locate degree symbol in Character Map, then Copy and Paste (see "Format Axis Label"). 3. Select -1. Then click Format | Selected Axis Title. On the Font tab, Effects: Superscript. *Note*: The *y*-axis label will temporarily be turned 90° so that it reads horizontally. When you finish with the formatting, click outside the figure and the label will return to its original orientation. 4. See (2).

2. To copy the graph, single-click the Chart Area (area inside the frame but outside of the axes). Selection handles will be displayed on the frame, indicating that the graph is activated. *Note*: If you mistakenly *double-click* the chart area, the Format Chart Area window comes up. Click **Cancel** to close the window.
   When the graph is activated, click the **Copy** button on the Standard toolbar (or **Edit | Copy** on the menu bar). The frame will then have moving dashes.
3. Move the cursor to the location in the Word document where you want to insert the graph. Click the **Paste** button on the Standard toolbar (or **Edit | Paste** on the menu bar). The graph will be pasted into the document at the position of the cursor. If you pasted the graph in the wrong place, click the **Undo Typing** button on the Standard toolbar or **Edit | Undo Typing** on the menu bar. If you notice an error in the graph, make the correction in Excel, and then copy and paste the graph again.
4. See Figures 4.1 and 4.4 in Chapter 4 for guidelines on how to refer to the figure in the text of the Results section of the report or paper and what constitutes a suitable figure caption.

Figure A2.13 shows the final form of the graph incorporated in the Results section of the report or paper.

Trendlines

Trendlines (also called regression lines or "best-fit" lines) are used to look for patterns in a data set and to make predictions about one variable when the other variable is known.

If you are looking for a pattern in a data set, first plot the data as a scatter plot (**Chart Wizard | Step 1 of 4 | XY (Scatter) | No points connected**). Figure A2.14A, for example, shows class data for a lab exercise in which we would like to know if there is a correlation between caffeine concentration and the change in pulsation rate of blackworms. While there is a significant variation in response for any given caffeine concentration, it looks like a bell-shaped curve might describe the pattern. In Figure A2.14B, a second-order polynomial trendline was fitted to the scatter plot by activating the chart and then clicking **Chart | Add Trendline | Type tab: Polynomial**, **2nd order** and **Options tab: Display equation on chart** and **Display R-squared value on chart**. The degree to which the trendline actually fits the data is given by the *R*-squared value,

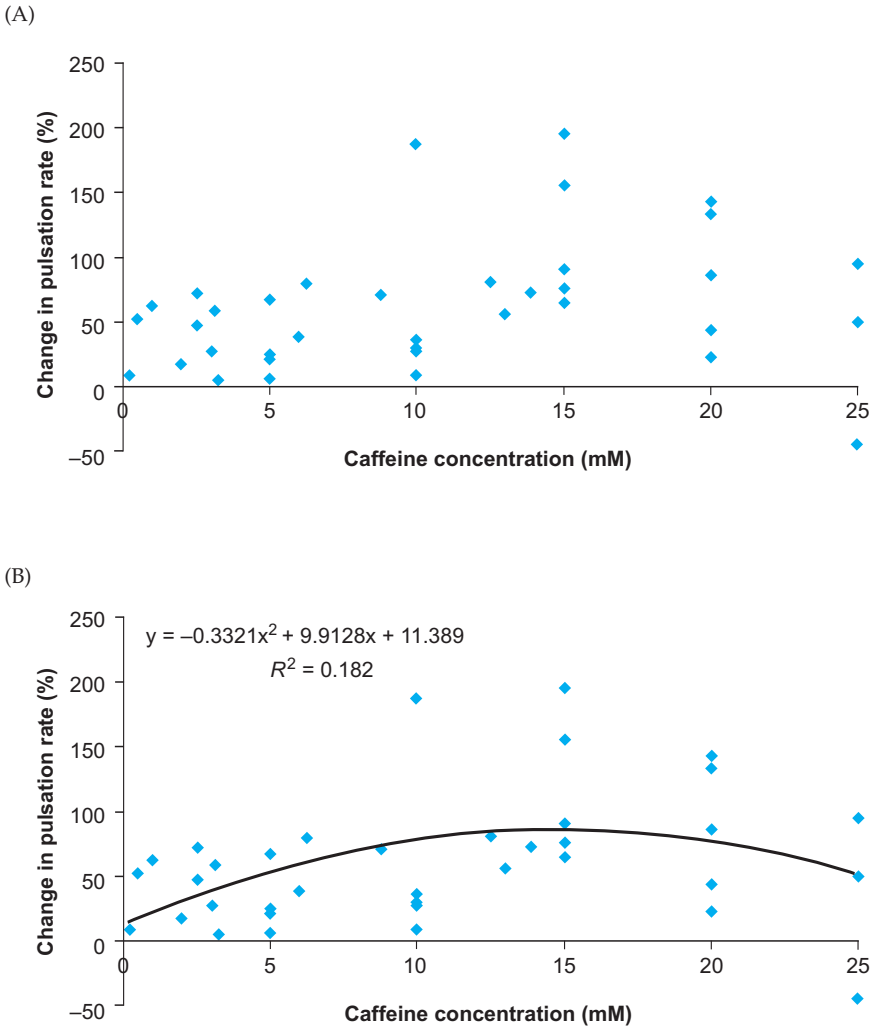

Figure A2.14 Effect of caffeine on the pulsation rate of blackworms. The percent change was determined by subtracting the rate before treatment from the rate after treatment, dividing by the rate before treatment, and multiplying by 100. (A) Data initially graphed as a scatter plot to look for possible patterns. (B) The same data with a second-order polynomial trendline fitted by Excel. The low R^2 value indicates that this trendline does not describe the correlation between change in pulsation rate and caffeine concentration very well.

whereby the closer the *R*-squared value is to 1, the better the correlation or fit. The low *R*-squared value in this example indicates that the second-order polynomial trendline does not describe the correlation between dose and response very well. We might conclude from these data that caffeine is a stimulant (because pulsation rate mostly increased at all caffeine concentrations tested), but that there is no clear relationship between caffeine concentration and response.

If your objective is to make predictions about one variable when the other is known, you may try to fit a linear trendline to the data set, as for a standard curve. Some examples in biology where standard curves are used include:

- Predicting the protein concentration of an unknown sample using the correlation between absorbance and known protein concentration (e.g., Biuret method, Bradford method).
- Determining the size of a DNA fragment by comparing the distance it migrated on a gel to the distance migrated by DNA fragments whose sizes are known.
- Quantifying nitrogen or phosphorous in aquatic ecosystems.

Do not insert a linear trendline when the data points do not fall on a straight line! If the data are not being used to make a prediction, just connect the points with straight or smoothed lines (**Chart Wizard | Step 1 of 4**, select **XY (Scatter) | Smoothed lines** or **Straight lines**).

Example: Standard Curve for a Protein Assay

Let's say you did an experiment in which you used the Biuret method to determine protein concentration in an egg white. In the first step of the procedure, you measured the absorbance of four known concentrations of bovine serum albumin (BSA) to make the standard curve. Because of Beer's Law, we expect the standard curve—a graph of absorbance vs. protein concentration—to be a straight line. Follow these steps to plot the standard curve:

1. Enter the BSA concentration in Column A and the corresponding absorbance values in Column B (Table A2.8).
2. Select the cells containing the data and click the **Chart Wizard** button. In Step 1 of 4, select **XY (Scatter) | No points connected**.
3. After completing the rest of the steps in Chart Wizard (see pp. 180–183), and modifying the background, borders, *x*-axis scale,

	A	B
1	2	0.10
2	3	0.12
3	5	0.24
4	10	0.40

TABLE A2.8 Sample data for Biuret standard curve. Protein concentrations (mg/mL) are entered in Column A, absorbance values (at 550 nm) in Column B.

and symbols according to CBE Manual guidelines, the resulting graph should look like Figure A2.15.

4. Single-click any point to activate the unconnected data set. All the data points should now be highlighted (yellow).
5. Select **Chart | Add Trendline** on the menu bar.
6. There are two tabs under the **Add Trendline** option: **Type** and **Options**. On the **Type** tab, select the default: **Linear**.
7. On the **Options** tab, check the boxes next to **Display equation on chart** and **Display R-squared value**. The equation allows you to predict the concentration in a sample of egg white (the "unknown") when its absorbance is known (measured). The *R*-squared value tells you how well the equation fits the data.

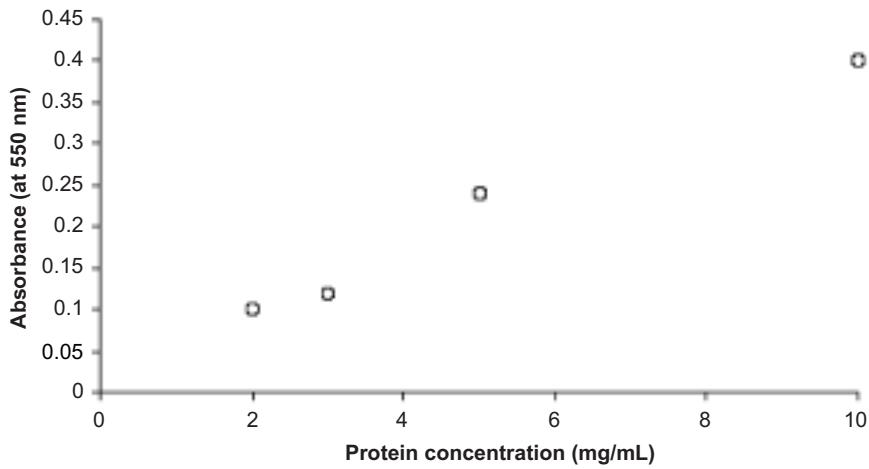

Figure A2.15 Biuret standard curve as a scatter plot. See Figure A2.16 for final form.

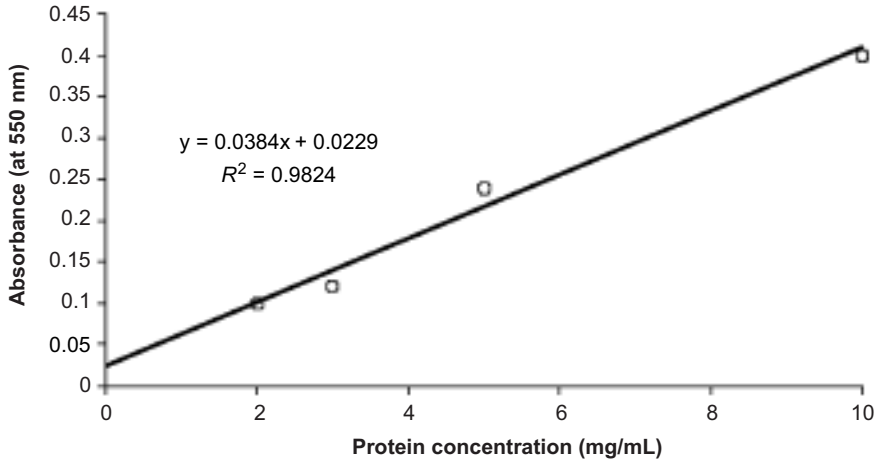

Figure A2.16 Biuret standard curve with trendline extrapolated backwards to the origin and the equation of the line displayed along with the R^2 value

8. Depending on the sensitivity range of the assay, it may be appropriate to extrapolate the linear trendline backwards or forwards. To do this, on the **Options** tab, set **Forecast Backward** (or **Forward**) the appropriate number of units. In Figure A2.16, "2" was entered for **Forecast Backward**.
9. Select **OK**. The resulting figure should look like Figure A2.16. *Note*: If desired, single-click the equation box to change *y* and *x* in the equation to the actual symbols for the variables.
10. **To modify an existing trendline**, right-click the trendline.
11. Follow the instructions given in the section "Importing Graphs into Microsoft Word" to copy the graph into your text document.

Multiple Lines on One Set of Axes

In some experiments it is desirable to compare the results from a number of different treatments. Plotting the data on one set of axes is often the most efficient way to convey this information. How many lines should you put on one set of axes? The CBE Manual recommends no more than 8, but use common sense. You should be able to follow each line individually, and the graph should not look cluttered.

Because there will be a multitude of lines on the figure, it is critical to identify the individual sets of data by means of labels or a legend. Excel

will generate a legend for each graph, provided you enter the appropriate titles in the spreadsheet. This can be accomplished by entering a short title in the first row of each of the data columns. These titles will be used by Excel to generate the legend.

Let's say you monitored the production of an enzyme called beta-galactosidase by *E. coli* grown under different conditions. Every 10 min for 1 hr, you measured the absorbance (which represents the concentration of beta-galactosidase) in each culture condition. Time is the independent variable that will be plotted on the *x*-axis. According to Excel convention, therefore, time should be entered in Column A. The next five columns will contain the absorbance data at each time for the five different conditions (Table A2.9).

1. Enter the data in the spreadsheet. Select all of the entries (column headings as well as numbers) and click the **Chart Wizard** button.
2. In Chart Wizard Step 1 of 4, Chart Sub-type, select **Scatter with data points connected** by smoothed or straight lines.
3. In Chart Wizard Step 2 of 4, make sure the data series is in **Columns**.
4. In Chart Wizard Step 3 of 4, make modifications to the following five tabs:

   Titles

   Chart Title: **Leave blank** if this graph is for a lab report or poster.

TABLE A2.9 Sample data for beta-galactosidase production in *E. coli* grown under five different conditions

	A	B	C	D	E	F
1	Time (min)	Mutant, Gly	WT, Gly	WT, Gly IPTG	WT, Glu	WT, Glu IPTG
2	0	2	0.205	0.1	0.04	0.044
3	10	2	0.265	0.88	0.095	0.174
4	20	2	0.406	1.4	0.2	0.214
5	30	2	0.351	2	0.23	0.3
6	40	2	0.386	2	0.33	0.442
7	50	2	0.56	2	0.35	0.468
8	60	2	0.67	2	0.42	0.91

Value (*X*) axis: **Enter the *x*-axis label with the units in parentheses**. In the current example: Time (min).

Value (*Y*) axis: **Enter the *y*-axis label with the units in parentheses**. In the current example: Absorbance (at 420 nm).

Axes

No changes.

Gridlines

There should be no gridlines on the figure. Clear the box next to Value (*Y*) axis: Major gridlines.

Legend

A legend (key) is required when there is more than one line on the graph. The box next to Show legend should be checked.

Data labels

None.

5. With so many lines on one set of axes, it is a good idea to **enlarge the graph** while still in Excel. Pull on a corner of the frame to make this adjustment.
6. **Change the plot area to white, remove the borders, change the symbols (markers), and adjust the scale of the axes** as described in Table A2.7.
7. Double-click the legend and **remove the border**. Drag the legend inside the axes.
8. The final graph should look something like Figure A2.17.

Multiple Trendlines on One Set of Axes

This is similar to the previous example, except that the lines are trendlines, instead of smoothed or straight lines connecting the data points.

Table A2.10 shows sample data for an experiment in which enzyme (catalase) activity was measured for different combinations of inhibitor (hydroxylamine) and substrate (hydrogen peroxide) concentrations. Column A gives the values for the *x*-axis ($1/[H_2O_2]$ (M)), while Columns B–E give the data points for the *y*-axis (1/units of product formed • sec^{-1}). Each column (line on the graph) represents *one* inhibitor concentration, which you enter in Row 1 for Columns B–E. These short titles are used by Excel to generate the legend.

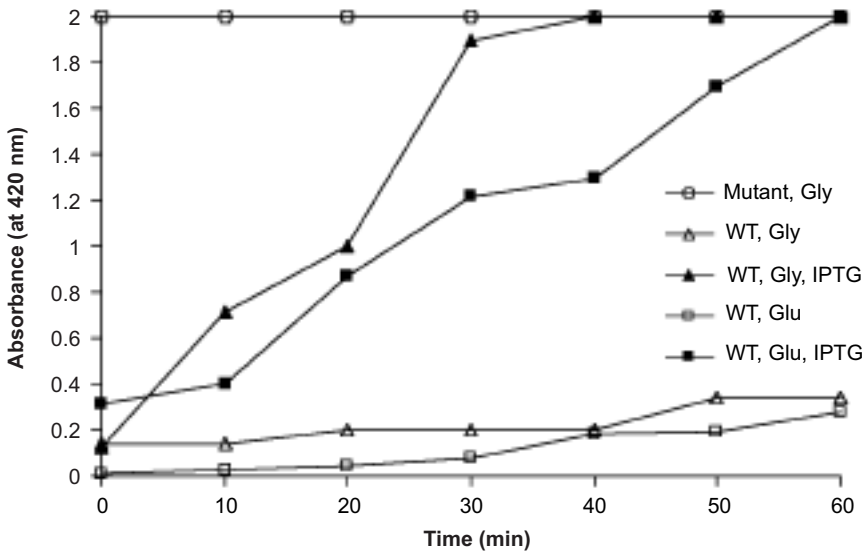

Figure A2.17 Beta-galactosidase production in *E. coli* grown under five different conditions. The mutant strain, which produces a non-functional repressor protein, was grown in glycerol. The wild-type strain was grown in glycerol or glucose, with or without the addition of IPTG (a lactose analog) at $t = 0$ min.

1. Enter the data in the spreadsheet. *Note:* The column titles must begin with I =, otherwise Excel confuses the number and percent symbol for a formula. Select all of the entries (column headings as well as numbers) and click **Chart Wizard**.
2. In Chart Wizard Step 1 of 4, Chart Sub-type, select **Scatter without connecting the points**.
3. In Chart Wizard Step 2 of 4, make sure the data series is in **Columns**.
4. In Chart Wizard Step 3 of 4, make modifications to the following five tabs:

   Titles

   Chart Title: **Leave blank** if this graph is for a lab report or poster.

   Value (*X*) axis: **Enter the *x*-axis label (unformatted) with the units in parentheses**. In the current example: 1/[H2O2] (M).

TABLE A2.10 Effect of hydroxylamine concentration on catalase activity for different concentrations of hydrogen peroxide

	A	B	C	D	E
1	1/[H2O2] (M)	I = 0%	I = 0.0025%	I = 0.025%	I = 0.25%
2	7.14	66.3	60.74	93.34	130.17
3	3.45	39.66	31.3	72.45	114.77
4	0.74	33.77	32.97	48.36	98.76
5	0.34	13.63	14.99	16.81	31.02

Value (*Y*) axis: **Enter the *y*-axis label (unformatted) with the units in parentheses**. In the current example: 1/Catalase activity (units of product formed sec–1).

Axes

No changes.

Gridlines

There should be no gridlines on the figure. Clear the box next to Value (*Y*) axis: Major gridlines.

Legend

A legend (key) is required when there is more than one line on the graph. The box next to Show legend should be checked.

Data labels

None.

5. With so many lines on one set of axes, it is a good idea to **enlarge the graph** while still in Excel. Pull on a corner of the frame to make this adjustment.
6. **Change the plot area to white, remove the borders, change the symbols (markers), adjust the scale of the axes, and format the axis labels** as described in Table A2.7.
7. Double-click the legend and **remove the border**.
8. Now we want to have Excel draw a linear trendline for each of the data sets. Click one of the symbols to select the data set. All the data points in that set should now be highlighted (yellow).
9. Select **Chart | Add Trendline** on the menu bar.
10. There are two tabs under the Add Trendline option: **Type** and **Options**. On the **Type** tab, select the default (**Linear**).

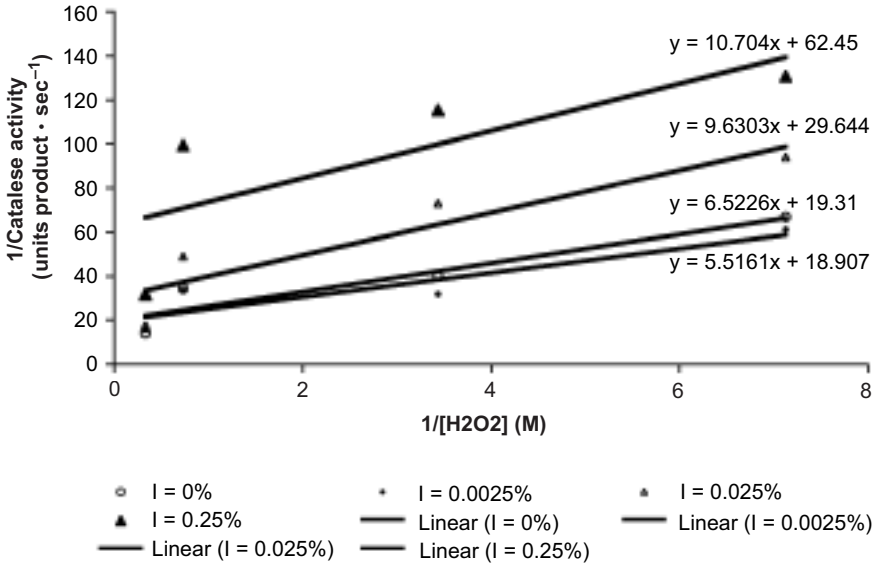

Figure A2.18 Effect of hydroxylamine concentration on catalase activity at different substrate concentrations. See Figure A2.19 for final form.

11. Now click the **Options** tab. Click the box next to **Display equation on chart**. The equations allow you to determine whether all the lines have a common *y*-intercept, a common *x*-intercept or neither. This information is used to determine whether hydroxylamine is a competitive or noncompetitive inhibitor in this reaction.
12. Select **OK**. The resulting figure will look something like Figure A2.18.
13. Since the "Linear" entries in the legend are meaningless, **single-click each of these text boxes** (to activate the frame), and then press the **Delete** key. Drag the legend inside the axes.
14. The resulting final graph will then look like Figure A2.19.

Figures as an Appendix to the Lab Report

Whenever possible, figures should be inserted in the document as close to their textual reference as possible. In some instances, however, you may be required to attach the figures on separate pages at the end of the report. To make the figure caption in that case:

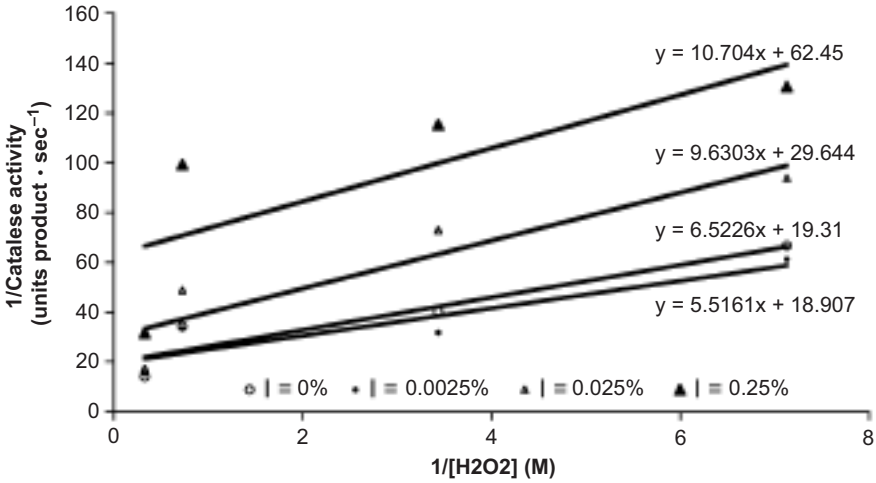

Figure A2.19 Effect of hydroxylamine concentration on catalase activity at different substrate concentrations

1. Follow the instructions given in the sections "Entering Data in Spreadsheet" and "Using Chart Wizard to Plot the Data" to make the first draft of the graph.
2. Modify the graph according to CBE Manual specifications (see Table A2.7).
3. When the graph is in its final form, single-click the Chart Area (the area inside the frame but outside of the axes).
4. From the menu bar, select **File | Print Preview | Set-up**.
5. Select the **Header/Footer** tab, and click the **Custom Footer** box. In the Left section of the footer area (which allows a maximum of 255 characters), type the word "Figure" followed by one space and then the appropriate figure number, followed by two spaces and then the figure title. Select the **A** box to change the font (Arial, regular, 12 pt is acceptable). Select **OK** to close all of the **Set-up** windows. The figure caption will be displayed in the proper position in the **Print Preview** window.
6. With the Chart Area still selected, click **File | Print**.

Importing Tables into a Word Document

Tables are handy for recording large amounts of data. Raw data should not, however, be included in your lab report or scientific paper. Furthermore, do not include both a table and a figure when they contain the same data.

Tables are preferable to figures in the following situations:

- To show precise numeric information rather than just the trend (as conveyed by a figure)
- To summarize information
- To describe information that is too complex to be shown in any other form

Because the Excel worksheet is really just one huge table, it may be easier to enter data in Excel, and then import the table into the Word document. Follow these steps:

1. Construct a well-organized table in Excel. Arrange the dependent variable data in columns with descriptive headings, so that like data are compared in columns, rather than across rows. If the variables presented have units, place the units in parentheses after the title in the column heading.
2. Use the mouse to select the data you wish to copy.
3. Click the **Copy** button on the Standard toolbar (or **Edit | Copy** on the menu bar).
4. Position the cursor in the Word document at the location where you wish to insert the table.
5. Click the **Paste** button on the Standard toolbar (or **Edit | Paste** on the menu bar).
6. Once the table is in the Word document, you can modify the table format (see Appendix 1, Section 2.12).